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Selva Rani A
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

S Subbulakshmi
Agricultural Research Station, Kovilpatti, Thoothukudi, Tamil Nadu, India

K Kavitha
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

S Nazreen Hassan
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

R Latha
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

S Suresh
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

Corresponding Author:
Selva Rani A
ICAR - Krishi Vigyan Kendra, Thirupathisaram, Kanyakumari, Tamil Nadu, India

A review on coconut based intercropping

Selva Rani A, S Subbulakshmi, K Kavitha, S Nazreen Hassan, R Latha and S Suresh

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Abstract
Coconut (*Cocos nucifera* L.) is an important perennial crop grown in the homestead garden as monocropping. It is a gift of nature and is cultivated worldwide because of its multiple uses. Coconut monocropping planting systems and growth habits effectively used only 22% of the land area, while canopy space utilization was around 30%, and solar radiation was around 45%. Coconut based cropping system depicts the arrangement of multispecies utilizing the available space, both horizontally and vertically, effectively on a sustainable manner. Intercropping results improvement in the soil properties and biological activities in the root region. Overall the microclimate is modified for the better crop growth and development. Income obtained per unit area of this system will be much more than from a corresponding area of pure plantation crop. It is viable in economically, environmentally and ensures rural prosperity in the coconut growing communities. The basic idea of intercropping is not only that two or more crop species grown together can exploit the resources better than either of them grown separately, but also cover inherent risk in agriculture and more so, under dryland condition which buffers to some extent and is called as "biological insurance" (Ayyer, 1963). Studies also revealed that sole crop of coconut with a spacing of 7.5 m x 7.5 m effectively uses only 22.3% of land area (Durieux, 1997), while the average air space utilization by the canopy is about 30% and solar radiation interception is about 50% (Thiruvarassan *et al.*, 2014; Dan *et al.*, 2005). Adoption of coconut based intercropping system is one of the ways to utilize natural resources effectively. The potential for increasing the productivity per unit area of land, time and inputs through coconut based cropping system is considerably higher net return per unit area in perennial crops (Bavappa and Jacob, 1982).

Keywords: Monocropping, intercropping, multispecies, insurance, utilization, return, perennial, significance

Introduction
Coconut scientifically known as *Cocos nucifera*, is a versatile and highly valued tropical fruit that has been cultivated and utilized by humans for thousands of years. The coconut tree is often referred to as the “tree of life” due to its various uses and the multitude of products derived from its different parts. The tree itself can grow up to 30 meters in height. It is primarily cultivated for its valuable products such as coconut oil, copra and coconut water. However the adoption of intercropping in coconut farming has gained attention due to its potential to enhance overall productivity and sustainability.

Intercropping in coconut involves planting secondary crops in the spaces between coconut trees, taking advantage of the vertical space available and the shade provided by coconut canopy. By integrating complementary crops within the coconut plantation, farmers can optimize land use, diversify income sources, and create a more resilient farming system. Studies also revealed that sole crop of coconut with a spacing of 7.5 m x 7.5 m effectively uses only 22.3% of land area (Durieux, 1997) [12], while the average air space utilization by the canopy is about 30% and solar radiation interception is about 50% (Thiruvarassan *et al.*, 2014; Dan *et al.*, 2005) [45, 8]. Adoption of coconut based intercropping system is one of the ways to utilize natural resources effectively. The potential for increasing the productivity per unit area of land, time and inputs through coconut based cropping system is considerably higher net return per unit area in perennial crops (Bavappa *et al.*, 1986 and Bavappa and Jacob, 1982) [4, 5].

The choice of intercrops in coconut cultivation depends on several factors, including climate, soil type and local market demand. Common intercrops in coconut plantations include banana, pineapple, legumes, root crops (elephant foot yam, cassava and sweet potato), spices (ginger and turmeric) various flowers and vegetables. These crops are selected based on their compatibility with coconut trees in terms of growth requirements, shade tolerance and market value.

Cocoa inter crop

Introducing food crops like coconut and cocoa would in the long run benefit to bring in livelihood security as well as food security in the disturbed and economically backward areas of the country. Ten prominent cocoa consuming companies in India require 60,000 MT of dry cocoa bean per year and it is growing at a rate of 15% per annum in domestic market. Current production is only 19000 MT per year, which shows that there is tremendous scope for introducing cocoa as a viable intercrop in coconut gardens. If cocoa cultivation is taken up in 10% of coconut area, the production will surpass the demand. This crop combination can become a regular source of income for the small and marginal coconut farmers in the country.

Coconut is highly amenable for different types of coconut based farming systems models with various crop combinations in intercropping, mixed cropping and multi-storeyed cropping etc., (Dhanapal, 2010) [11]. India produced 19,866 tonnes of cocoa beans from 88,515 hectares with a productivity of 580 kg ha-1 in the year 2020 (DCCD, 2020) [9]. More than two-thirds of cocoa are grown in coconut (Thomas *et al.*, 2010) [46] and around a fifth with arecanut (Sujatha *et al.*, 2011) [43]. The structure and orientation of the adult coconut78 canopy permit about 55% active radiation to penetrate down (Nelliat, 1979) [35] and the gardens spaced at 7.5 m × 7.5 m offer wide purview for intercropping with suitable, biennial, seasonal and perennial crops, including cocoa, leading to a sustainable increase in the production and productivity per unit area (Nath *et al.*, 2019) [31].

Maintenance of optimum canopy shape involves pruning certain branches as it is known in cocoa that highly shaded leaves do not show photosynthetic activity and penetration of sunlight to stimulate cocoa flowering and fruit setting (Uchoi *et al*., 2018). The enhancement in nut yield of the coconut by intercropping is also supported by the findings of Bhalerao *et al*. (2018) [6] and Nath *et al*. (2019) [31]. Cocoa has been found biologically compatible and physiologically adaptive in coconut gardens (Jnanadevan, 2018) [17]. The congenial of microclimate due to intercropping coupled with increased microbial activities and improvement in soil fertility might have favoured the growth and yield of coconut (Nair and Balakrishnan, 1977 and Nair and Rao, 1977) [29, 30]. The improvement in nut yield of the main crop by intercropping has been reported earlier by Basavaraju *et al*. (2011) [3] and Maheswarappa *et al*. (2013) [22].

Coconut and cocoa require tropical climate. Coconut requires an equal climate with high humidity. The ideal mean annual temperature is 27 °C with a well distributed rainfall of 1000 mm to 3000 mm per annum. Cocoa requires moderate climate with a temperature range of 15-39 °C with optimum of 25 °C and annual rainfall of 1000 to 2500 mm. Both coconut and cocoa thrive well in a wide range of soil like laterite, coastal sandy or sandy loam soils rich in organic matter. Both the crops are sensitive to water stress and water logging. The ideal soil requirement of cocoa is humus rich forest soil. The natural habitat of cocoa is the dense shade of the warm rain forests. The soil should allow easy penetration of roots and capable of retaining moisture during summer. Clay loams, loams and sandy loams are suitable for cocoa. Shallow soils should be avoided. Cocoa is grown on soils with a wide range of PH from 6-7.5 where major nutrients and trace elements will be available. Cocoa does not come up in coastal sandy soils where coconut flourish.

Cocoa has been found biologically compatible and physiologically adaptive in coconut gardens. Coconut provides shade to cocoa which is a shade tolerant crop requiring 40-70% light for better yield. The diffused sunlight in coconut garden is ideal for growing cocoa.

The differences in the plant height and tree girth of cocoa trees have been attributed to various factors such as environmental factors, soil moisture, availability of nutrients and genetic factor of the tree. Similar differences in the plant height and stem girth of clones and hybrids have been reported by Elain Apshara *et al*. (2009) [13] and Sumitha *et al*. (2018) [6]. In cocoa, yield is determined by yield contributing characters such as number of pods, dry bean yield per tree per year and pod value.

Cocoa intercropping in coconut plantations can provide several advantages, including efficient land use, diversification of income, and improved ecological balance. However it requires proper management practices and an understanding of the specific requirements of both crops.

Pruning is an important practice to ensure proper ventilation within the crown and penetration of sunlight to stimulate cocoa flowering and fruit setting. These characters are influenced both by genetic as well as environmental factors which include soil moisture and nutrient status. The congenial of microclimate due to intercropping coupled with increased microbial activities and improvement in soil fertility might have favoured the growth and yield of coconut (Nair and Balakrishnan, 1977 and Nair and Rao, 1977) [29, 30]. The improvement in nut yield of the main crop by intercropping has been reported earlier by Basavaraju *et al*. (2011) [3] and Maheswarappa *et al*. (2013) [22].

Banana intercrop

Banana intercropping in coconut refers to the practice of growing banana plants in the spaces between coconut trees. The intercropping technique allows farmers to maximize land use and increase overall productivity. Rationally, monoculture of coconut plantation can't guarantee the prosperous farmers. The light transmission trough the canopy varies follows plant age and almost it is contrary with the covering of canopy. Furthermore, it is recorded that the highest coconut canopy coverage was in 8 - 30 years age, in conventional spacing 9m x 9m triangular pattern, the canopy coverage is only 60%, then, over 30 years, the coverage could be only 20%. It is reported that 86% of coconut root was only be found in 30-130 cm in depth E.V. Nelliat, *et al*., 1974 [34]. Therefore, the land maximum effectively used is only at radius 2 m (S.S. Magat, *et al*.., 1999) [20]. In Kenya, plantain or banana intercropped are reported to be one of the most profitable coconut intercrops E.V. Nelliat, 1974 [34]. Plantain or banana intercropped are reported to be one of the most profitable coconut intercrops, J.G. Ohler. 2007.

Pepper intercrop

Pepper intercropping in coconut cultivation is a common practice followed by farmers to maximize land productivity and generate additional income. In coconut cultivation pepper vines are often grown as an intercrop due to their compatibility with coconut trees. Coconut based high density multi-species cropping system is recommended to obtain maximum income and better utilization of resources. The crops grown under this

system include fruits, vegetables, spices *etc*. Black pepper (*Piper nigrum* L.), an important spice crop, is generally a component under coconut based cropping systems.

Black pepper (*Piper nigrum*) is one of the most important spice crops and several studies showed that, black pepper can be grown successfully with coconut (Nagawekar *et al*., 2002; Sadanandan, 2000) [28, 40]. High rainfall in the black pepper growing areas made the soil less productive due to leaching and erosion losses of nutrients and has effect on growth of the crop (Sadanandan, 2000) [40]. Evaluation of black pepper varieties carried out by earlier workers (Potty *et al*., 1979; Mathew *et al*., 1993; Sadanandan *et al.*, 1993) [39, 24, 41] in the multi-storeyed cropping system and mixed cropping system indicated better performance of Panniyur-1 variety.

Sruti *et al*., (2013) [42] reported that, black pepper bulk density ranges from 460.6 to 608.7 g L-1. Bulk density is the major physical property and it influences directly the market price of black pepper (Lam *et al.*, 2008) [19]. It is also having impact on storage requirements, the sizing of the material handling system and how the material behaves during subsequent thermo-chemical and biological processes. Several studies (Maheswarappa and Anithakumari; c2005; Palaniswami *et al*., 2007) [21, 38] reported that, under high density multispecies cropping system, black pepper provided additional yield and there was improvement in the yield of coconut.

Flower inter crop

India has traditionally been a profound place for floriculture and gardening. Although flower cultivation has been practiced since time immemorial, floriculture has blossomed into a viable business only in recent years. Floriculture activity has been envisioned as a profitable trade area with the potential to activate self-employment among farmers with low and middle income. Availability of natural resources like diverse agro-climatic conditions permits the production of a wide range of temperate, tropical and subtropical flowers, almost all through the year in some parts of the country or other. Improved communication facilities increased their availability throughout the country. The commercial activity of production and marketing of floriculture products is also considered as a source of gainful and quality employment to people.

Several researchers have taken up experiments with a variety of flower crops for checking their suitability as an intercrop under coconut plantations for gaining sustainable additional income (Ghosh *et al*., 2017) [15]. Significant differences were also noticed for average number of flowers harvested under two types of coconut plantations. Increased flower bud number and flower diameter in plants grown under higher light intensities have been recorded by Zieslin and Mor in roses. Thakur *et al*., 2019 [44]. Also stated decrease in flower yield of *R. damascena* monocrop with increasing shade levels as compared to sunny conditions. The reproductive growth of the plants depends upon availability of assimilates and its increased transport to the young shoots (Mass and Bakx, 1995) [23]. The availability of assimilates can be increased either by higher rates of photosynthesis or by shifting in partitioning of assimilates (Mor *et al*., 1981., Mortensen *et al*., 1992) [26, 27]. Availability of light positively influences the assimilate partitioning in roses (Mor *et al*., 1981) [26]. The phenomenon of increase in the flower yield under more intensity is probably associated with increased irradiance for photosynthesis or assimilation by plants.

The basic idea of intercropping is not only that two or more crop species grown together can exploit the resources better than either of them grown separately, but also cover inherent risk in agriculture and more so, under dryland condition which buffers to some extent and is called as "biological insurance" (Ayyer, 1963) [2]. Studies also revealed that sole crop of coconut with a spacing of 7.5 m x 7.5 m effectively uses only 22.3% of land area (Durieux, 1997) [12], while the average air space utilization by the canopy is about 30% and solar radiation interception is about 50% (Thiruvarassan *et al.*, 2014; Dan *et al.*, 2005) [45, 8].

Adoption of coconut based intercropping system is one of the ways to utilize natural resources effectively. The potential for increasing the productivity per unit area of land, time and inputs through coconut based cropping system is considerably higher net return per unit area in perennial crops (Bavappa *et al*., 1986 and Bavappa and Jacob, 1982) [4, 5]. Many authors reported successful inter cultivation of floricultural crops such as, Marigold, Chrysanthemum, China Aster, Gerbera, Zinnia, Tuberose, Antirrhinum, Gladiolus, Bird of Paradise, Ornamental Zinger, GlobeS Amaranth under coconut plantation (Desai *et al*., 2018; Nihad *et al*., 2016; Nihad *et al*., 2017) [10, 36, 37].

Desai *et al*. (2018) [10] suggested the intercropping of chrysanthemum, China aster crops under coconut plantation to get higher returns and positive influence of these crops on plant health and productivity. A speciality flower crop 'Heliconia' was evaluated under coconut and identified as a remunerative intercrop for coconut gardens Nihad *et al*., 2016) [36]. Higher returns from Marigold-Gomphria sequential intercropping under coconut gardens was also reported (Nihad *et al*., 2017) [37]. Marigold (*Tagetes spp.*) is popular flower intercrop due to their ability to repel pests and attract beneficial insects. They have bright, showy flowers that attract pollinators and can be grown as a protective border around cocnut plantations. Sunflower are not only appealing but also attract bees, butterflies and other pollinators. Chrysanthemum (*Chrysanthemum* spp.) are widely grown their attractive flowers and provide an additional source of income.

CPCRI (2003) [7] reported that among the flowering crops grown in coconut garden Heliconia and Anthurium had a good vase life. It was also reported that out of five Jasminum genotypes tried in coconut shade, J. pubescence was found to grow well than all other genotypes tested in coconut shade. Arunachalam and Reddy (2007) [1] reported that large variety of crops have been found suitable for growing under irrigated and rain fed conditions in coconut garden including flowering crops like *Heliconia*, *Anthurium*, *Jasminum* sp. Floricultural crops could be cultivated in association with coconut leads to many advantages *viz*., an increase in the yield of coconut, extra income from intercrops as well as more employment opportunities etc. Flower intercropping to enhance biodiversity and attract pollinators.

Nelliat, (1978) [33] reported that in coconut garden 60% of the space is utilized for coconut and 40% sunlight are left unutilized which provides ample scope for introducing compatible inter crops in the interspace of coconut. In humid tropics, higher efficiency of utilization of basic resources of crop production *viz*. land, solar radiation and water can be achieved by adopting intensive cropping system (Nelliat, 1974) [33]. Intercropping is popular because of many advantages like increased productivity per unit area, better use of available resources, (land, labor, time, light, water and nutrients),reduction in damage caused by pests, diseases, weeds and socio economic factors (greater stability, economics, human nutrition and biological aspects) as reported by Vandermeer (1989) [47]. In coconut based cropping systems cultivation of compatible crops in the interspaces of coconut offer considerable scope for increasing production and productivity per unit area, time and inputs by more efficient utilization of natural resources like sunlight, soil, water and

labor. Jayakumar *et al*. (2017) [16] reported that water and nutrients are the major inputs contributing to higher productivity of crops. In perennial crops like coconut, where the land remains committed to the same crop for several decades, one of the feasible ways of increasing the production is to raise compatible inter crops in the interspaces.

Conclusion

Intercropping in coconut plantations is a traditional practice in small lands, but it is rare in large-scale systematic cultivation. Coconuts take up the most plantation space, but they yield the lowest net return per acre and give the fewest jobs. Therefore, different economically valuable crop species such as intercrops in coconut plantations must be popularized. Sunlight, land, water, and labor are the factors that are effectively utilized in a coconut-based intercropping system. This will improve land productivity, resource utilization, economic viability, and global food security. Also coconut plantation diversification enhances the biodiversity of the environment. Diversified intercropping system could be one of the solution to realize sustainable productivity and maximum income per unit area of land besides maintaining soil fertility by the recycling of by-products of crops since land being a renewable resource, must be put to maximum use for increased crop production.

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